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(12) UK Patent (19) GB (11) 2 372 143 (13) B

(45) Date of publication: 09.04.2003

(54) Title of the invention: Flow field plate geometries for a fuel cell,  
including for a polymer electrolyte fuel cell

(51) Int Cl<sup>7</sup>: H01M 8/02

(21) Application No: 0103390.1

(22) Date of Filing: 12.02.2001

(43) Date A Publication: 14.08.2002

(52) UK CL (Edition V):  
H1B BF500 BF502

(56) Documents Cited:  
WO 2001/004982 A WO 1994/021372 A

(58) Field of Search:  
As for published application 2372143 A viz:  
UK CL (Edition S) H1B  
INT CL<sup>7</sup> H01M 8/00  
Other: On line databases  
WPI,EPODOC,JAPIO  
updated as appropriate

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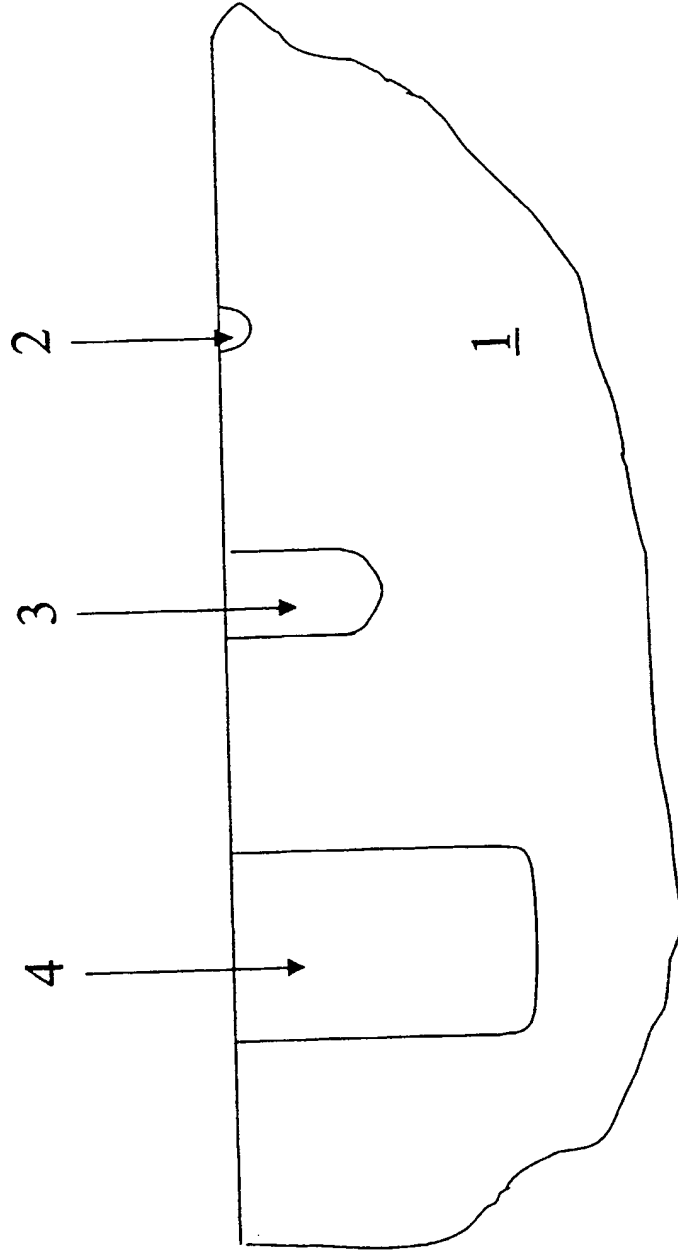


Fig. 1

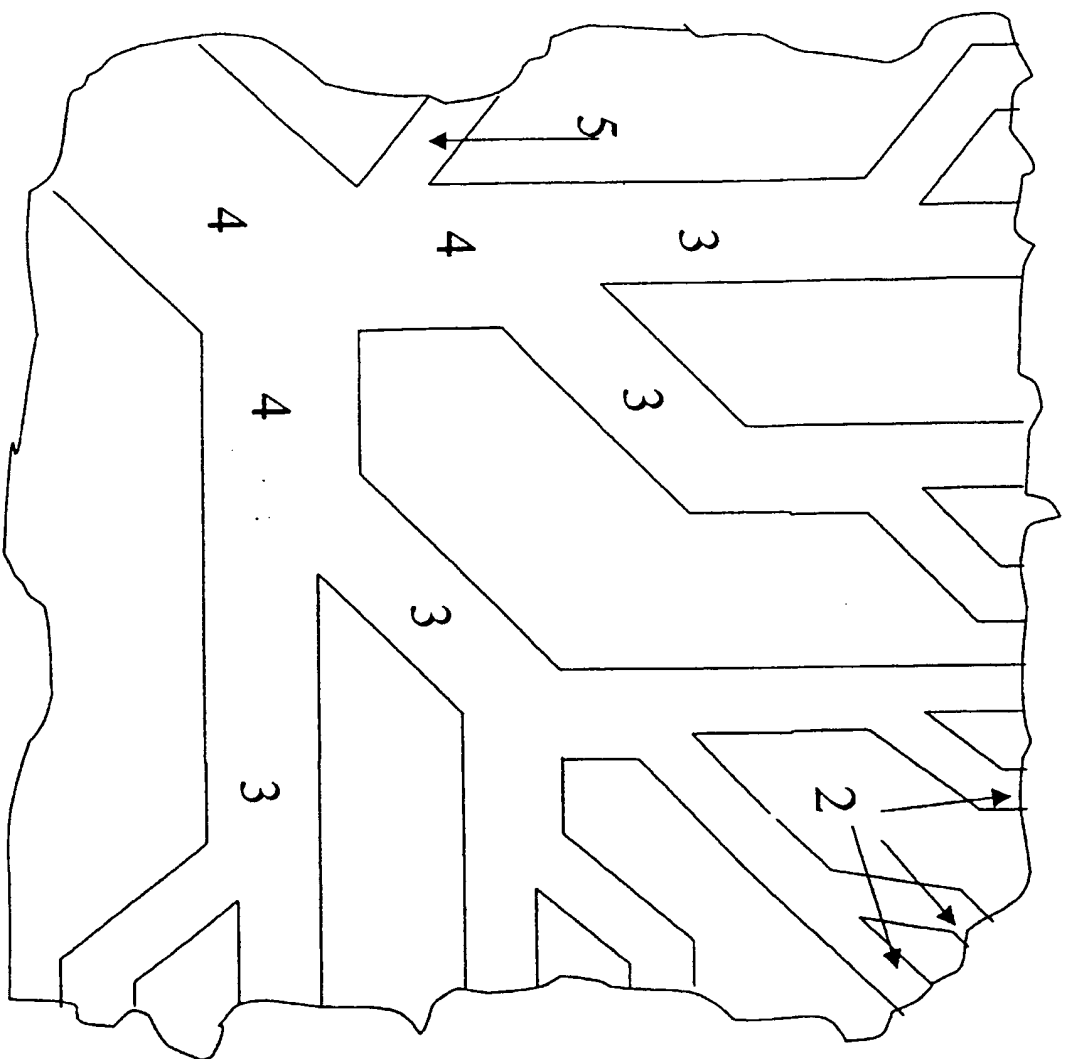


Fig. 2

FLOW FIELD PLATE GEOMETRIES FOR A FUEL CELL, INCLUDING FOR A  
POLYMER ELECTROLYTE FUEL CELL

This invention relates to fuel cells and is particularly, although not exclusively, applicable to  
5 proton exchange membrane fuel cells.

Fuel cells are devices in which a fuel and an oxidant combine in a controlled manner to produce  
electricity directly. By directly producing electricity without intermediate combustion and  
generation steps, the electrical efficiency of a fuel cell is higher than using the fuel in a  
traditional generator. This much is widely known. A fuel cell sounds simple and desirable but  
10 many man-years of work have been expended in recent years attempting to produce practical  
fuel cell systems.

One type of fuel cell in commercial production is the so-called proton exchange membrane  
(PEM) fuel cell [sometimes called polymer electrolyte or solid polymer fuel cells (PEFCs)].

Such cells use hydrogen as a fuel and comprise an electrically insulating (but ionically  
15 conducting) polymer membrane having porous electrodes disposed on both faces. The  
membrane is typically a fluorosulphonate polymer and the electrodes typically comprise a noble  
metal catalyst dispersed on a carbonaceous powder substrate. This assembly of electrodes and  
membrane is often referred to as the membrane electrode assembly (MEA).

Hydrogen fuel is supplied to one electrode (the anode) where it is oxidised to release electrons  
20 to the anode and hydrogen ions to the electrolyte. Oxidant (typically air or oxygen) is supplied  
to the other electrode (the cathode) where electrons from the cathode combine with the oxygen  
and the hydrogen ions to produce water.

In commercial PEM fuel cells many such membranes are stacked together separated by flow  
field plates (also referred to as bipolar plates). The flow field plates are typically formed of  
25 metal or graphite to permit good transfer of electrons between the anode of one membrane and  
the cathode of the adjacent membrane. The flow field plates have a pattern of grooves on their  
surface to supply fluid (fuel or oxidant) and to remove water produced as a reaction product of  
the fuel cell. Various methods of producing the grooves have been described, for example it has  
been proposed to form such grooves by machining, embossing or moulding (WO00/41260), and  
30 (as is particularly useful for the present invention) by sandblasting through a resist  
(WO01/04982).

To ensure that the fluids are dispersed evenly to their respective electrode surfaces a so-called gas diffusion layer (GDL) is placed between the electrode and the flow field plate. The gas diffusion layer is a porous material and typically comprises a carbon paper or cloth, often having a bonded layer of carbon powder on one face and coated with a hydrophobic material to promote water rejection. It has been proposed to provide an interdigitated flow field below a macroporous material (US-A-5641586) having connected porosity of pore size range 20-100µm allowing a reduction in size of the gas diffusion layer. Such an arrangement permits gas flow around blocked pores, which is disadvantageous. Build up of reactant products (such as water) can occur in these pores reducing gas transport efficiency. Additionally, such a structure increases the thickness of the flow field plate.

A combined flow field plate and gas diffusion layer has been described in US-A-6037073 and comprises a selectively impregnated body of porous carbon material, the impregnation hermetically sealing part of the plate. Such an arrangement has the drawbacks that it is complicated to make reproducibly and that it permits gas flow around blockages as in US-A-5641586.

An assembled body of flow field plates and membranes with associated fuel and oxidant supply manifolds is often referred to a fuel cell stack.

Although the technology described above has proved useful in prototype and in some limited commercial applications, to achieve wider commercial acceptance there is now a demand to reduce the physical size of a fuel cell stack and to reduce its cost. Accordingly, a reduction in the number of components could have beneficial results on size and cost (both through material and assembly costs). Also, the prior art flow field plates have provided flow fields of serpentine, linear, or interdigitated form but have not looked to other physical systems for improving the gas flow pathways.

The applicants have realised that by forming sufficiently fine channels on the face of the flow field plates the purpose of distributing the gas evenly across the electrodes can be achieved without the use of a separate gas diffusion layer. They have further realised that by looking to physiological systems (the lung) improved flow field geometries may be realised that are likely to have lower parasitic losses due to their shorter gas flow pathways.

The present invention therefore provides a bipolar plate for a fuel cell comprising on at least one face an assembly of channels comprising one or more gas delivery channels, and a plurality of finer gas diffusion channels of width less than 0.2mm connecting thereto.

5 The gas delivery channels may comprise one or more primary channels of a width greater than 1mm, and a plurality of secondary gas delivery channels of a width less than 1mm connecting thereto.

The gas diffusion channels may form a branched structure.

10 The gas diffusion channels may be of varying width, forming a branched structure of progressively diminishing channel width similar to the branching structure of blood vessels and air channels in the lung.

The invention is illustrated by way of non-limitative example in the following description with reference to the drawing in which:-

Fig. 1 shows schematically in part section a part of a fluid flow plate incorporating gas delivery channels and gas diffusion channels formed by sandblasting.

15 Fig. 2 shows schematically a partial plan view of a fluid flow plate incorporating gas delivery channels and gas diffusion channels.

20 To form both gas delivery and gas diffusion channels a technique such as sand blasting may be used in which a template or resist is placed against the surface of a plate, the template or resist having a pattern corresponding to the desired channel geometry. Such a technique is described in WO01/04982, which is incorporated herein in its entirety as enabling the present invention. With this technique the plates may be formed from a graphite/resin composite or other non-porous electrically conductive material that does not react significantly with the reactants used.

25 It is found with this technique that the profiles of channels of different width vary due to the shadow cast by the mask. Fig. 1 shows a flow field plate 1 having a narrow channel 2 formed in its surface. Because of the shadowing effect of the resist used in forming the channel the channel is exposed to sandblast grit coming effectively only from directly above. This leads to a generally semicircular profile to the channel and to a shallow cutting of the channel.

For progressively larger channels (3 and 4) the resist casts less of a shadow allowing sandblasting grit from a progressively wider range of angles to strike the surface of the flow field plate, so allowing both deeper cutting of the surface and a progressively flatter bottom to the channel.

- 5 Accordingly, by applying a resist with different width channels to a plate and exposing the plate and resist to sandblasting with a fine grit, a pattern of channels of different widths and depths can be applied.

Applying such a pattern of channels of varying width and depth has advantages. In flow field plates the purpose behind the channels conventionally applied is to try to ensure a uniform  
10 supply of reactant material to the electrodes and to ensure prompt removal of reacted products. However the length of the passage material has to travel is high since a convoluted path is generally used.

Another system in which the aim is to supply reactant uniformly to a reactant surface and to remove reacted products is the lung. In the lung an arrangement of progressively finer channels  
15 is provided so that air has a short pathway to its reactant site in the lung, and carbon dioxide has a short pathway out again. By providing a network of progressively finer channels into the flow field plate, reactant gases have a short pathway to their reactant sites.

The finest channels could simply discharge into wide gas removal channels or, as in the lung, a corresponding network of progressively wider channels could be provided out of the flow field  
20 plate. In the latter case, the two networks of progressively finer channels and progressively wider channels could be connected end-to-end or arranged as interdigitated networks with diffusion through a gas diffusion layer or through the electrode material providing connectivity. Connection end-to-end provides the advantage that a high pressure will be maintained through the channels, assisting in the removal of blockages.

- 25 The question of interconnected channels vs. blind channels depends on which side of the electrode we are dealing with. Hydrogen ions travel from the anode, through the polymer, and are made into water at the cathode. All of the water is made on the cathode or oxygen side of the cell. The water generation on the cathode side means that the air side gas channels cannot be blind ended, as this would cause flooding. Interdigitated will also be tricky unless a GDL is  
30 used as the permeability of the electrode is not high. Accordingly, the model wherein the branched channels join end to end or drain to a larger channel is preferred.

Fig. 2 shows in a schematic plan a portion of a flow field plate having broad primary gas delivery channels 4, which diverge into secondary gas delivery channels 3 which themselves diverge into gas diffusion channels 2. Gas diffusion channels 5 can also come off the primary gas delivery channels 4 if required. The primary and secondary gas delivery channels may each form a network of progressively finer channels as may the gas diffusion channels and the arrangement of the channels may resemble a fractal arrangement.

The primary gas delivery channels may have a width of greater than 1mm, for example about 2mm. A typical depth of such a channel is 0.25mm but depth is limited only by the need to have sufficient strength in the flow field plate after forming the channel. The secondary gas delivery channels may have a width of less than 1mm, for example 0.5mm and will be shallower than the primary gas delivery channels. The gas diffusion channels have a width of less than 0.2mm, for example about 100µm and will be shallower still.

By providing such a structure, reactant products have a short distance to travel and can be removed efficiently in comparison with conventional plate designs. Additionally, gas channels in typical bipolar plates are of square or rectangular section and are millimetric in size. E.g. Ballard™ plates have a 2.5mm square section channel. APST™ plates have a channel that is 0.9mm wide by 0.6 mm deep. Smaller channels are beneficial as the pressure drop per unit length is higher and the pressure drop is what drives the reactants into the diffusion media.

WO00/41260 has an extensive discussion of flow field design but has not appreciated that by providing extremely fine channels (less than 0.2mm) and by providing such channels as part of a network of progressively diminishing width, the pressure drop between adjacent channels is minimised so avoiding short-circuiting of the flow field.

The primary channel(s) must be of a size sufficient to deliver the working volume of gas required by the cell. This is about 25L/min per kW of working power.

The flow field plates may be used with a gas diffusion layer, or the gas diffusion channels may be provided in a sufficient density over the surface of the flow field plate to provide sufficient gas delivery that a gas diffusion layer may be omitted.

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The limit on channel width is a function of the mask thickness used in the sand blast process. Image Pro™ materials (Chromaline Corp. US), are very thick at 125 micron. These masks limit track width to about 100 microns. Other mask materials can be spray coated onto the substrate and exposed in situ. These materials are much more resilient and hence can be much thinner.

5 Chromaline SBX™ can be used to etch features down to 10-20 microns wide.

As well known, (see for example WO00/41260) the same pattern of grooves does not need to be applied to both faces of a flow field plate and the present invention is not limited in this way.

## CLAIMS

1. A bipolar plate for a fuel cell comprising on at least one face an assembly of channels comprising one or more gas delivery channels, and a plurality of finer gas diffusion channels of width less than 0.2mm connecting thereto.
2. A bipolar plate as claimed in Claim 1, in which the gas delivery channels comprise one or more primary channels of a width greater than 1mm, and a plurality of secondary gas delivery channels of a width less than 1mm connecting thereto.
3. A bipolar plate as claimed in Claim 1 or Claim 2, in which the gas diffusion channels form a branched structure.
4. A bipolar plate as claimed in Claim 3 in which the gas diffusion channels are of varying width forming a branched structure of progressively diminishing channel width.
5. A bipolar plate as claimed in any preceding claim comprising a first assembly of channels for gas delivery and a second assembly of channels for removal of reactant products.
6. A bipolar plate as claimed in claim 5, in which the first and second assemblies of channels are interdigitated.
7. A bipolar plate as claimed in any preceding claim in which channels decrease in depth with diminishing width.
8. A bipolar plate as claimed in any preceding claim in which the gas diffusion channels are provided in a sufficient density over the surface of the bipolar plate as to form an integral gas diffusion layer.
9. A fuel cell stack comprising a plurality of bipolar plates as claimed in any one of Claims 1 to 7.

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